Deforestation as a Multifaceted Problem; a Cross-National Econometrics Approach

Research Thesis

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by

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Abstract

Deforestation is a growing worldwide issue. According to the Food and Agriculture Organization of the United Nations (FAO), between 2000 and 2010, deforestation has resulted in a net forest loss of 5.2 million hectares per year which is equivalent to the area of Costa Rica. Prior large-scale research on deforestation stressed either the pressure of population growth or economic development as the main drivers of deforestation. At the more local level, case studies have demonstrated that in addition to socioeconomic processes, environmental variation, patterns of energy consumption and governance are often critical. Thus, in the attempt of questioning deforestation with policy, there is the need to formulate a model that extends globally yet is sensitive to each individual country's variation, at the same time taking into account environment, socioeconomic, energy and governance factors. With an ordinary least squares model comprised of 187 countries, the dependent variable of deforestation is regressed against the diverse spectrum of independent variables. Preliminary findings have demonstrated the explanatory power of a broader range of variables. By formulating a condensed model of deforestation, it is proven that all four categories of variables explain certain extend of variation in deforestation across countries. In spite of the fact that the socioeconomics processes segment of the model indicated significant correlation to deforestation, it encompassed more variables than merely pressure of population growth and economic development. Therefore, in examining the issue deforestation, research should not solely analyze any limited dimensions, but expand the scope to all aspects that are equally important in driving deforestation.

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Acknowledgements

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Introduction

Nestled in the lush corner of Asia, the physical landscape of Malaysia has left a lasting imprint on my interest of studies. Being a pre-eagle scout, I spent much of my teenage years in the forest and was mesmerized at the majestic creations of Mother Earth. Those experiences intensified my curiosity on figuring out how the world operates. Under the wing of my mentor who acted as both my geography teacher and scout leader, he instilled in me a love of geography into me as he often amazed me with his detailed explanations on the various natural phenomena. Years flew by and destiny brought me thousands of miles away from my homeland. Then, one day, while reminiscing on the fascinating scenery of Malaysia, the image of a hazy sky struck my mind. I'm not a stranger to this recurrent image, resulting from the irresponsible undertaking neighboring Indonesia, who adopted the swidden approach to deforestation. Thus, that laid the foundation of this research that aimed to elucidate deforestation. Originally from a cultural background which exposed me to diverse individuals and communities, I am intrigued by how the differences between distinct agents play out in varying contexts. That perception is further amplified by the classes I took with both Dr. Munroe and Dr. Ettlinger on how economics and geography span across different realms. Bearing that thought in mind, I set out my research to take into account of all the possible drivers of deforestation and how these diverse variables intertwine with each other. Aware of the need to be sensitive to the local circumstances, I intend to encompass how deforestation differs accordingly to proxies for the characteristics of land, socioeconomic and culture, energy consumption and the implications of governance. However, when constructing the initial blueprint of this research, I intended to incorporate the approach from both the fields of geography and economics. Fortunately, I was on the right path as the econometrics classes conducted by Dr. Farivar gave a great deal of insight of how viable my quest of expanding the questioning of global deforestation through econometrics was. Some made me ponder whether my project was too illustrious or if I should narrow down my scope and just take the easier route of tapping the readymade resources. Remaining upbeat and persevering through the different setbacks, I'm glad that this research turned out to be a very rewarding experience.

However, I would like to underline the distinction between the view and approaches to deforestation from economics and geography. Institutions such as the World Bank dominated by economists, presented their view in the World Development Reports that spatial transformation from forest to cities and trade is a requirement for countries to develop (Rigg et al, 2009). Other than that, economists tend to make assumptions and simplify the linkage between variables via the usage of equations. Most of the research conducted by economists on the subject of deforestation is restricted to a limited range of processes. In addition to that, economists construct models of deforestation based on the history of the developed nations to forecast the current progress of developing nations. Moreover, the economic approaches on deforestation are often core-to-periphery where there is a top-down apparatus that governed by hierarchical institutions.

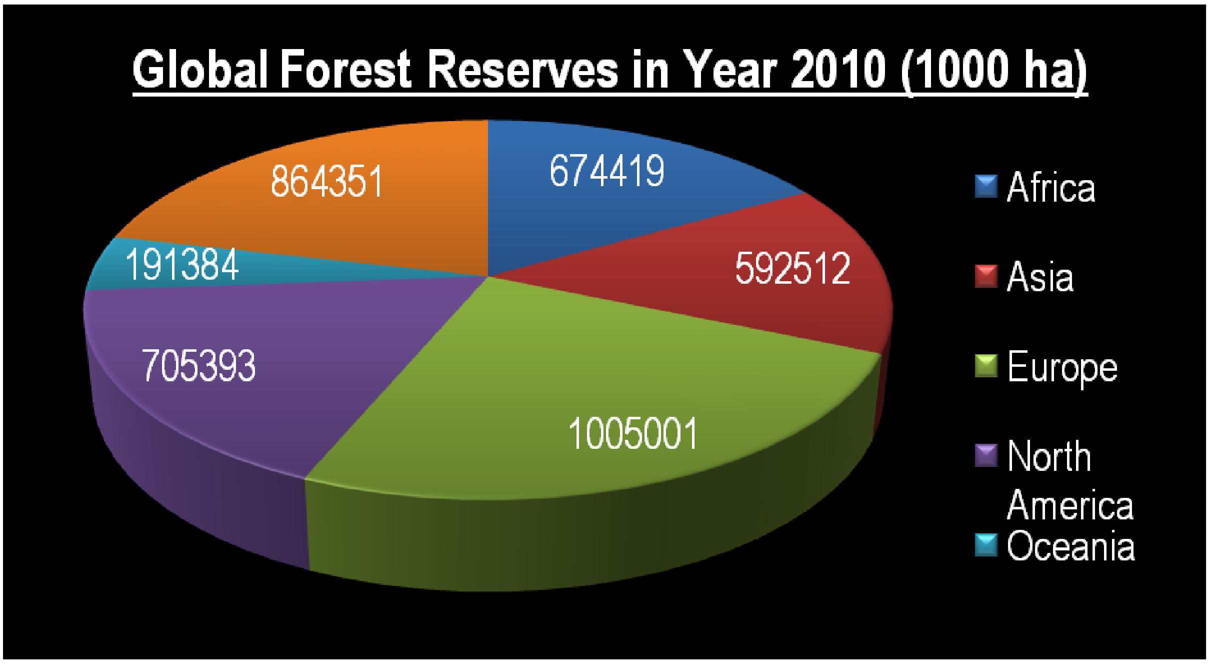
On the other hand, geography recognizes the disparity of different actors in playing out deforestation. Ergo, the geographical approach is more robust and encompasses various agents at all the different scale of analysis. Furthermore, contrasting to the view of economists on deforestation, geographers perceive deforestation as the process of outsourcing of developed countries to developing nations which retain much of their forest reserves. Rather than dwell on the matter of efficiency and economics returns, geographers criticize the Reducing Emissions from Deforestation and Forest Degradation (REDD) program and exposed the inherent creation of carbon credit market. Contradicting to the analysis of economists based on qualitative data such as figures that fit into an equation, the geographical approach consists of qualitative analysis whose inputs are diverse. Remote sensing technology and Geographic Information Systems (GIS) are both instrumental methods for geographers in analyze deforestation.

Deforestation

Through the years, with the ever increasing momentum generated by environmentalists' concern on global warming, much attention was placed by various expertise to elucidate the environmental imprints that left behind by our trail of economic development. At the annual net loss of forest area of a Costa Rica (FAO, 2010), a forest of the size of Ohio will be deforested in two years. This is indeed an alarming rate and serves as a wake-up call for everyone to acknowledge the worrisome situation that caused by human development. Although the subject of deforestation has been examined under the microscope for decades, there is never a singular explanation on the complex and varied causations of deforestation (Geist & Lambin, 2002). Thus, there is yet to be any definite policy recommendation which able to eradicate deforestation.

Preliminary studies on global deforestation first involved the breakdown analysis on the forest reserve across continents. Shown in **Pie Chart 1** is the distribution of global forest reserve in year 2010 in the unit for area of 1000 ha. Europe apparently owned the highest reserve of forest area as the vast Russian forest of 0.8 billion ha upsurges the total percentage of European forest to land area up to 45%. It is followed by South America where the great Amazon forest is nestled. The North America continent comprised by both North and Central America possesses the third largest forest reserve. Then it is the continent of Africa that contained approximately 0.7 billion ha of forest. Whereas for Asia, a great source of forest area is from China and the rest are scattered across the different countries. Lastly, Oceania with comprised of a large area of forest from Australia completes the list.

<u>Pie Chart 1: Global Forest Reserve across Continents in year 2010 (1000 ha)</u>



Preliminary Theorization with EKC

The Environmental Kuznets Curve (EKC) and deforestation serves as the outset of this study. The inverse-U shaped Kuznets Curve that named after Simon Kuznets; the 1971 Nobel Prize in Economics winner laid the backdrop of this paper. Initially, the original Kuznets Curve proposed the hypothesis that as a nation develops, at first income inequality increases, and subsequently decreases after attaining a certain average income per capita (Kuznets, 1955). However, the Kuznets Curve was revised by Grossman and Krueger's research on the environmental impacts of the North American Free Trade Agreement and evolved into what known today as Environmental Kuznets Curve (1991). Describing the interrelationship between environmental degradation and income per capita, the EKC proponed that along with economic growth, various environmental qualities would degrade until the nation's income reach a tipping point whereby the trend reverses, so that higher income level leads to environmental improvement (Grossman & Krueger, 1995). However, geographer such as Gavin Bridge propone an alternative explanation to the EKC. With a greater integration of socio-economic systems through globalization, there is an evident trend of 'dematerialization' of economic growth in industrial economies that reflected the international division of labor (Bridge, 2009). In other words, the declining trend of EKC is supported by the outsourcing of material-intensive production to the peripherals such as the South. On one hand, there is the suggestion that hypothesized that the EKC framework corresponds to a country's transition from agrarian society to industrialized economies to tertiary industry, which supported the validity of the curve (Arrow et al., 1996; Dinda, 2004). On the other hand, there is a wide array of critics that focus on the empirical analysis on the parameter of pollutants that against the trend of EKC (Stern, 2004; Shafik & Bandyopadhyay, 1992). The research conducted by Shafik and Bandyopadhyay indicated that only two of ten examined indicators of environmental pressure consisted to the EKC path. On top of that, Roy Chowdhury and Moran emphasized on the importance of defining the explanatory variables together with the "space-time substitution" approach, in order to achieve the inverted U-shaped curve (2010). They stated that most of the studies on EKC adopted the cross-sectional analyses to compensate the absence of sustainable data. Hence, rather than monitoring the progress of environmental condition as the nation develops through time, contemporary approach of these studies were to select a sample of countries to represent the varying stage of economic development (Roy Chowdhury & Moran, 2010). That exhibits an inherent defect in the analysis of EKC as it neglected the fundamentals such as variation of power, social-economic and asymmetric relations. On the other hand, researchers like Joanne Burgess, who is interested on how timber trade affects deforestation, found out that rather than stressing on the intuitive linkage of higher timber export to deforestation, one needs to realize that the profit from timber export will lead towards better forestry investments and sustainable management of forest area (1993). Whereas, the significance of trade in deforestation is echoed by DeFries et al. who highlight the importance of urban-based and international demand for agricultural products (2010). Their findings suggest that urbanization increases the demand for agricultural products which should be tackled by allocating more attention on industrial-scale deforestation, export-oriented agriculture and increase crops yields (DeFries et al, 2010).

EKC and Deforestation

However, how does EKC come into place with respect to deforestation? Researchers like Ehrhardt-Martinez et al. began to question the problem of deforestation through the application of EKC whereby they studied the inverted U-shaped rate of deforestation in relation to economic development (2002). Through the application of ecological modernization theory (EMT), they concluded of the presence of a “self-corrective” mechanism whereby more advanced economies have the capacity to reposition themselves towards environmental well-being. The research also took into account a more diverse scope of actors of deforestation and their findings on EKC proved the influence of agglomeration and urbanization, rural-to-urban migration, urban service sectors and democracy.

The vantage point of applying a cross-sectional analysis is shared by Bhattarai and Hammig who are intrigued by the theory of EKC and how it plays out in the macro-level (2001). In addition to the relationship of income on deforestation, they highlighted both the processes of institutional structure and macroeconomic policy and rejected the notion of a generalized one-size-fits-all policy to reform deforestation. In contrast to the typical emphasis of population growth, they pointed out that with the inclusion of institutional structure, the distribution of population whether rural or urban are more significant than merely population growth.

Empirical Research

Thus, the presumption that deforestation is mainly driven by individual land users is not appropriate as it ignores interlinks between various drivers. Thus, rather than focus primarily either on population pressure or economic development, there is the necessity to expand the scope of research and synthesized the interactions between various subjective and objective knowledge on deforestation (Nonaka & Takeuchi, 2005). Serving as the genesis for this paper that attempts to encompasses various variables, Angelsen and Kaimowitz (1998, 1999) summarized a total of some 150 economic deforestation models that adopted both the macro or micro-level vantage point of analysis. Through their summarization, they managed to identify the possible causes of deforestations that are direct causes in inducing deforestation, immediate reasons that affect the decision parameters and agent characteristics, and underlying causes of broader scope of forces that affects agents' decisions (Angelsen & Kaimowitz, 1998). In addition to that, the paper introduced the various building blocks of deforestation that can be analyzed through different scopes of micro, meso and macro level. Micro level of household and firm formed the cell of deforestation and that involved "Open Economy model" that assumed perfect competition and mobile factors of production, whose variation in independent variables determined the degree of deforestation; "Subsistence and Chayanovian model" that involved imperfect labor market where market wage plays minimum role in allocating resources. In such instance, the farmers' devotion of effort is torn between subsistence whereby households try to attain a level of consumption with minimum labor or Chayanovian by which household trade-off consumption with leisure; and "Empirical and Simulation model" that involved the time-consuming data collection by skilled surveyor to produce regression or models. On the next level, the meso or regional level consisted of "Spatial Simulation model" that utilized technologies such as Geographical

Information System (GIS) to analyze land-use pattern and Dynamic Ecological-Land Tenure Analysis (DELTA) to simulate household behavior spatially; “Spatial Regression model” that measures the correlation of land-use with other geo-reference variables and time series analysis with multivariate logit or probit analysis; and “Non-Spatial Regional Regression model” that focus on county, provincial, state or region with Ordinary Least Squares (OLS) and Feasible Least-Squares (FGLS). The last category of macro or national level analysis composed of “Analytical model” that assumed land and labor as the only factors of production and take into consideration of the price factor on deforestation; and the “Computable General Equilibrium (CGE) model” which is made up of a conventional approach that hypothesized agents clear forest until the marginal profit or land rent is zero, a property rights approach which examines forest’s property rights and its impacts explicitly, and a forest rotation approach that regarded deforestation as an “intertemporal allocation” issues whereby the cost-aware agent maximized profit in response to the ideal period.

With that, Angelsen and Kaimowitz’s meta-analysis provided a great insight into the problem of deforestation both through different geographical scales and dimension of agents and simultaneously, shed light on the possible range of independent variable that this study aimed to achieve and emulate.

Analysis on Diverse Geographical Scales and Dimensions

Nonetheless, the questioning of the global deforestation took place through various geographical scales. Some (Zhang et al., 2001; Purnamasari, 2010; Chomitz & Gray, 1996) examined it at the level of a specific state or country, whereas others (Lopez & Galinato, 2004; Angelsen & Kaimowitz, 2001) conducted of a region. As an example, with the assumption that the price of land differs accordingly to each land’s categories and profitability, Zhang et al. conducted a generalized least square analysis across the counties in

Hainan Island, China and further applied the Cochrane-Orcutt transformation to deal with the strong autocorrelation between variables (2001). They recognized the significance of population pressure, afforestation and de-collectivism, and how these factors influenced the pace of deforestation. Moreover, there is also the need to take into account both the spatial distribution of deforestation (Anselin, 2002) and the pattern of land use change (Irwin & Geoghegan, 2001; Lambin et al., 2003; Rudel et al., 2005). Irwin and Geoghegan are interested in particularly on the human behavior component of land management and strived to investigate the causal relationship on economic process that associated with spatial land use change. With that vantage point, their paper is made up of three distinct models of empirical model, hybrid model and spatially-explicit model whereby each strive to explain through remotely sensed data and GIS, simulation model of land-use change under different exogenous scenario and maximization of profit by landowners in Less Developed Countries (LDCs) (Irwin and Geoghegan 2001). Their insight has further driven home the influence of humans in conducting research.

Methodology and Specification of Model

This research began with the intention of attempting to rationalize deforestation by encompassed the vast spectrum of possible causes to deforestation and not centered merely on any single dimension. In contrast to the dependent variable of environment degradation that proposed under the EKC framework, Shafik (1994) pointed out that the rate of change in forest cover can serve as good indicator as the rate of deforestation. Hence, an econometrics model was constructed with the dependent variable of the change in forest cover. The Global Forest Resources Assessment (FRA) from the Food and Agriculture Organization of the United Nation is the first major piece of puzzle. The FRA 2010 contributed the vital data on the dependent variable with annual rate of forest change from year 2005 to 2010 and its sample size of 233 countries laid the backdrop of the research with.

The regression model is encompassed by four major categories of independent variables, namely *Environmental Variation, Socioeconomics Processes, Pattern of Energy Consumption and Governance*.

Environmental Variation

Concerning the significance of location and land quality (Pieri et al., 1995), the first segment of *Environmental Variation* is captured by the "*Type of Topsoil", "Acidity of Land", "Difference in Elevation", "Precipitation",* and *"Composition of Primary Forest".* The global dominant topsoil was classified by the FAO Land Resources and International Institute for Applied Systems Analysis (IIASA) accordingly to the process of which the soil conditioned and its subsequent characteristic. The World Soil Resources Report (1993) analyzed the potential of different type of soil individually of which inherently affect its fertility and its potential for either agriculture or other commercial usage, has affirmed the importance of including "*Type of Topsoil"*. Chomitz and Gray examined the relation of soil quality to the construction of rural roads which eventually led to deforestation (1996). They hypothesized that agriculturally poor land are prone to transform into rural road that facilitate deforestation. Other studies also factorized in the explanatory capabilities of the environmental variation. Geist and Lambin (2002) underpinned their stance that no single variable unilaterally affect forest cover change. Their findings drive home the need of a greater understanding of the synergies between the land characteristics and other underlying drivers which are specific to a given location. Whereas, Ochoa-Gaona and Gonzalez-Espinosa's studies on the state of Chiapas in southern Mexico revealed that soil types does determine the location and rate of clearing for agriculture and forestry (2000). On the other hand, the process of deforestation is underlying by elevation. Investigating the Indonesian island of Sumatra, Kinnaird et al. classified elevation into separate categories and examined the rate of deforestation in relation to each of the group. Their finding proves that the clearing of forest is more rapid at flat lowland than steep hill or montane forest (Kinnaird et al., 2002). The implication of acidity of soil on the suitability for agriculture and its subsequent tendency to be deforested was mentioned by the Ministry of Agriculture, Food Security and Co-operative Tanga of Tanzania (2006). Crops vary in their optimum acidity for growth but extremes of soil pH will stunt the growth of roots. Hence, soil that is suitable for the cultivation for any specific crop will inherently prone for afforestation. Regarding the relation between percentage of primary forest and deforestation, Sader and Joyce suggested on how the clearing of forest in Costa Rica progressed toward the interior by the inward expansion of roads network and further reduced the composition of primary forest (1988).

Socioeconomic Processes

The *Socioeconomic Processes* sphere (Perz, 2002) is made up by "*Annual Population Growth Rate", "Composition of Rural Population", "Median Age", "Age Group of Zero to Fourteen", "Age Group from 15 to 64", "Age Group Over 65 Year Old", "Gross Domestic Product", "Dominant Religion", "Land under Cereal Production", "Share of GDP in Agriculture", "Net Inflow of Foreign Direct Investment",* and *"Roundwood Extraction"*. Palo's examination on how deforestation is driven by population signifies the inclusion of the "*Annual Population Growth Rate"* whereby much forest area is cleared in order to accommodate the ever expanding society (1994). Cropper and Griffiths pointed out the magnitude of population is reflected in the FAO with its estimation of deforestation that geared particularly towards population pressures (1994). While Templeton and Scherr are concerned of the impacts inflicted by population density on hilly-mountains for agricultural production and the effects of subsequent technology investments that focus on the planted-tree density (1997). In addition to that, the model is comprised of the *"Composition of Rural Population"* in comparison to the total population. As it is the people who stay at rural areas that first turn to agriculture as the mean of sustenance, it is logical to relate rural population to deforestation (Cropper and Griffiths 1994). This segment of model also encompassed *"Median Age"* and the demographics' age group of *"Age Group from Zero to 14"*, *"Age Group from 15 to 64"* and *"Age Group who over 65 years old"*. The component of age in explaining deforestation was presented by both Cline-Cole et al. and Godoy et al. Focusing on the impacts of household determinants on deforestation of the Amerindians in Honduras, Godoy et al. found out that age bore a positive correlation to forest clearance (1997). Their result proven that young households deforest for more land to accommodate the inheritance of their children. However, when the children move out and the physical strength of aging residents deteriorates, the amount of forest cleared drops (Godoy et al., 1997). Furthermore, the examination of deforestation in Africa by Cline-Cole et al. is consistent to the significance of age. Women of child-bearing age have extra demand for fuel wood, in particular during the confinement for childbirth. In a similar manner, children and elderly usage of heating fire is higher in the population (Cline-Cole, Main, & Nichol, 1990). The analysis from Moran et al. on the relation of household demographic with deforestation in Amazon mirrored the justification of a trend in land management as household ages (Moran, Siqueira, & Brondizio, 2004). Younger households with very young children and low supplies of capital will turn towards annual crops to stock up their capital and transform biomass of forest into fertilizer for fast growing crops. These households will then shift to pasture and cash and labor-demanding livelihood. With the new generation reaching marriageable age, new young household born but the pre-existing aging household will switch towards crops that guarantee steady revenue. Thus, as nation's population ages, there is considerably less young generation and subsequently, the people will no longer demand as much arable land as before. The variable of *"Gross Domestic Product"* is included to reflect the fundamental building blocks of EKC. When the size of a nation's economy expands through primary sector, more land is demanded. However, with gradual transition into manufacturing and service-based economy, the clearing of forest is reduced as a considerably higher productivity is achievable at every square foot. With the increase in GDP, people will substitute energy sources away from wood fuel and at the same time, adapt advance agricultural technique that demand less arable land (Cropper & Griffiths, 1994). The model extended to the *"Dominant Religion"* and how the relation between human and its surrounding environment differs across different religious disciplines (Van Wormer, Besthorn, & Keefe, 2007). Deacon (1999) supported the significance of religion through an historical analysis whereby ancient Greeks and Romans enacted many laws and stiff fines to preserve their scared groves of trees. However, the rise of Christianity along with its anthropocentric concept, gave rise of destruction of groves which regarded as symbol of pagan religion. Along the same line, under Islam rules, all lands are commons for all to the commons to cultivate, hence leave a devastating effect on the natural vegetation (Deacon, 1999). Byers, Cunliffe and Hudak (2001) studied the implication of traditional religious beliefs on the deforestation of sacred forests in Zimbabwe. Their results indicated the degree of forest loss is considerably less in area that regarded as sacred and whose traditional religious leader command more authority. The vantage point of socioeconomics also involves the area of land in each nation that allocated for cereal production. This *"Land under Cereal Production"* variable is considerably substantial in countries whose economy still based in primary sector. As more land is needed for cultivation of cereal either through industrialized method (monocultures, multiple cropping and intercropping) or the destructive slash-and-burn method, more forest area is clear out to support the subsistence of community (Zikri, 2009). In coherent to that, it is wise to consider the *"Share of GDP in Agriculture"* that suggest that nations that have a larger share of GDP in agriculture would inherently demand more arable land. Other than that, the channeling of foreign direct investment (FDI) also played a prominent role in the process of deforestation and is captured by *"Net Inflow of*

Foreign Direct Investment". Nations that with higher inflow of foreign investment will construct large-scale industrial development which further minimize the forest area (Seto & Kaufmann, 2003). The variable of *"Roundwood Extraction"* is one of the underlying sources of deforestation. Similar to increasing agricultural land, the demand for the application of wood primarily as raw material can exert enormous pressure on the sustainability of forest (Geist & Lambin, 2002) In the case of deforestation in India, Haeuber credit the loss of forest to the increasing commercialization of forestry that influenced by India's post-independence economic strategy that reserved forest for industrial usage (1993). Thus, the Indian forestry was geared towards roundwood production with extensive survey of forest for extraction potential, improvement of logging procedures and research on maximization for raw material from all timber species.

Pattern of Energy Consumption

On the other hand, the category of *Pattern of Energy Consumption* encompassed the variables of "*Woodfuel Extraction", "Price of Super Gasoline", "Generation of Hydropower",* and *"Volume of Energy Consumed"*. Haeuber (1993) emphasized on the deforestation which exerted by the demand for woodfuel. In the case of India which highly dependent on woodfuel to cook, woodfuel plantations would have to expand in order to accommodate the rising demand for rural domestic use that experienced shortage due to the new classification by government that restrict the traditional sources of forest products from wasteland. Whereas the *"Price of Super Gasoline"* reflected the cost of transportation, which on one hand is highly correlated with the cost of diesel that consumed by the heavy vehicle in the process of deforestation and conveyance; and on the other hand, it implies the cost and ease of population dispersion. On top of that, a higher fossil fuel price will drive up the demand of biofuel which consequently led to the expansion of monocultures of oil palm, soy and other biofuel crops that resulted in deforestation and loss of biodiversity (Koh & Wilcove, 2008). Other than that, the energy price and its effect on biofuel production will affect the food prices (Mitchell, 2008). Due to the incentives that provided by European Union (EU) and the United States government for biofuel production, the increase demand for maize and oilseeds push up the global food price and consequently affects the incentive for peasants to deforest (Barrett, 1999). With The variable on the *"Generation of Hydropower"* by each country is included as an indicator of the amount of renewable energy used to reduce the reliance on non-renewable energy such as wood fuel or fossil fuel , and conversely in some case, the loss of forest area through flooding to creating artificial dams. The last variable that fall into this category is the *"Volume of Energy Consumed"*. Energy consumption is found out to be correlated to a nation's income level as more energy is required for a higher production of goods and services for economic growth (Asafu-Adjaye, 2000). Therefore, country that engaged more intensively in the manufacturing and service industry would require less land mass.

Governance

The last segment of the economic model involves the key component of *Governance.* In his book of "Logjam: Deforestation and the Crisis of Global Governance", Humphreys presented the troubling global governance of deforestation (2006). He identified the key institutions, policies and the failure of international bodies in curbing deforestation. Besides that, governance that are both politically and economically-driven, tend to give in to continuous degradation of forest. This section is made up by the variables of the "*Area of Permanent Forest", "Percentage of Public Ownership of Forest", "Participation in International Convention and Agreements", "Number of Established Legal Framework",* and *"Form of Government"*. The indicator of "*Area of Permanent Forest"* reflected the incentive for deforestation to take place for its potential economics values. A nation that owns a higher percentage of permanent forest might have greater tendency to deforest as they still own a considerably larger forest reserves. The next variable in this grouping is the ownership of the forest area. The variation in ownership of whether it is under public or private ownership will have direct implications. Land that under public ownership need to undergo more thorough consideration from various government agencies and in some cases, resistance from the public. However, forests are merely assets and means to gather more profits in the eyes of capitalist that ignore the shortcomings that they might inflict on the environment. The stability of forest ownership also plays a vital role in the effort to conserve and impose forest law (Deacon, 1999). In the times of war and revolution that led to the breakdown of the system of ownership, forests are subjected to more exploitation and less investment as more attention is diverted for more prioritized agenda. Other variable which is significant in this model is the *"Participation in International Convention and Agreements"* such as Kyoto Protocol and multilateral organization like United Nations Framework Convention on Climate Change (UNFCCC) and Convention on Biological Diversity (CBD). Through participating in these treaties, these nations are subjected to the guidelines and requirements. In their studies on the relation between tropical deforestation and Kyoto Protocol, Santilli et al. (2005) found out that substantial effort was exerted to reduce deforestation level of the participating nations under the Kyoto Protocol. However, they pointed out the existence of "market leakage" in which participants cease their rate of deforestation but compensate it through higher import of forestry products from non-participating nations. In the context of Kyoto Protocol, the Annex I countries which primarily made up by developed countries are credited when their carbon stock increase but forest destruction in developing countries is not debited. Thus, Annex I nations could cease their domestic harvest or export and substituted it with more import from developing countries (Santilli et al. 2005). Along the same line, referring to Forest Principles that were enacted in year 1992, as it is non-legally binding and only served as recommendation, it left a minimal mark in averting deforestation (Humphreys, 2006). Santilli et al. also revealed the need of a greater stimulus for developing nations such as Brazil and Indonesia whose large portion of economy is dependent on the export of their forest products, to minimize their rates of deforestation (2005). Besides that, the model also included the presence of internal national regulation to manage its forest with *"Number of Established Legal Framework"*. Nations that established a complete self-regulation policy are more capable of instilling a systematic rule on the forest and consequently abate the widespread of deforestation. On top of that, the *"Form of Government"* is taken into account too. As different institutional framework varies in terms of its operation and distribution of authority, it has distinctive influences on forest management. Different forms of government have varying degree of either public or private funded infrastructure investment that provide access to forest area, level of national debt, political stability and security of property rights which all contribute towards to the management of natural capital of forest (Deacon, 1994).

Collection and Descriptive Statistics of Variables

With the theoretical construction of the econometrics model, the next step of the research proceeded with the compilation of data for each variable into spreadsheets in Excel. **Table 1** listed the descriptive statistics and individual source of quantitative variables and subsequently, **Table 2** for qualitative variables. In order to capture the effect of data that presented as zero, dummies were constructed for countries that have zero cereal production and zero share of agriculture in GDP. Whereas, for qualitative variables such as type of topsoil, religion and form of government, dummy variables were utilized for each specific

Table 1: Descriptive Statistics of Quantitative Variables

Variables	Description (Unit)	Minimum	Maximum	Median	Mean	SD	Sources
Environmental Variation							
Acidity of land	pH	3.5	8.5	6.5	6.2941	0.79252	FAO (2007)
Differences in Elevation	Maximum –Minimum (meters)	2.4	9004	2438	2767.2	1993.4	CIA (2012)
Precipitation	Average precipitation in depth (mm/ year)	51	3200	1030	1158.8	784.9	Worldbank
Composition of Primary Forest	Percentage of primary forest to total area	0%	100%	2%	13.749%	0.21997	FAO (2010)
Socioeconomic Processes							
Annual population growth rate	Population of 2008	-1.2%	12.6%	1.3%	1.4205%	0.013549	FAO (2010)
Rural Population	(Percentage of total population in 2010)	0%	89%	42%	43.481%	22.954%	Worldbank (2012)
Median age	Age that divides a population into half	15.1	44.9	26.9	28.317	8.3539	CIA (2012)
GDP	2010 GDP as per current U.S dollars (billion)	0.214	14527	22.963	333.94	1277.3	IMF (2011)
Age Group (0-14)	Estimation of age structure on year 2011	13.1%	49.9%	27.5%	28.284%	.10433	CIA (2012)
Age Group (15-64)	Estimation of age structure on year 2011	48.0%	78.7%	65.7%	63.909%	.066799	CIA (2012)
Age Group (>65)	Estimation of age structure on year 2011	0.9%	22.9%	6.1%	7.8107%	0.053015	CIA (2012)

Land under cereal production	(hectares)	0	9.6740e+007	6.1238e+005	3.7389e+006	1.1268e+007	Worldbank (2012)
Composition of agriculture of a nation's GDP	Agriculture includes farming, fishing, and forestry	0	76.9	9.4	13.759	14.051	CIA (2012)
Foreign Direct Investment, Net Inflows	2010 (BoP, current US$)	-4.1989e+010	2.3623e+011	6.22e+008	6.7578e+009	2.6371e+010	Worldbank (2012)
Roundwood Extraction	Total Volume of 2005 (1000m^3 over bark)	0	4.8101e+005	506	9470.3	41453	FAO (2010)
Pattern of Energy Consumption							
Wood fuel Extraction	Total Volume of 2005 (1000m^3 over bark)	0	2.6075e+005	732	8414.0	25595	FAO (2010)
Price of Super Gasoline	(US Cents/ litre)	2	253	109	105.39	39.808	GTZ (2009)
Generation of Hydropower	Total Hydro Production of 2008 (Kilowatt-hours, million)	0	5.8519e+005	1415	17540	63669	UN Data (2012)
Energy Use	(kg of oil equivalent per capita)	9	19240	947	2042.6	2810.4	Worldbank (2012)
Governance							
Area of Permanent Forest	(1000 ha)	0	2.8559e+005	87	9407.3	35834	FAO (2010)
Percentage of Public Ownership of Forest		0	100	76	63.615	37.463	FAO (2010)
Participation in international convention and agreements	Status of ratification of international conventions and agreements as of 1 January 2010	0	9	8	7.7326	1.8384	FAO (2010)
Number of Established Legal	Existence of national policy, national forest program and	0	3	3	2.1390	1.0836	FAO (2010)

Framework	forest law as of year 2008						
Independent Variable							
Annual Forest Change Rate	Rate of gain or loss of the remaining forest area between 2005 and 2010	-9.71	3.58	0	-0.15118	1.2814	FAO (2010)

Table 2: Descriptive Statistics of Qualitative Variables

Variables	Description (Unit)	Mode	Composition	Frequency	(%)	Sources
Type of Soil	Dominant top soil	Cambisols	1-Soils conditioned by seasonally dry or humid subtropical and tropical climate and long evolution (Ferrasols, Acrisols, Lixisols, Nitisols, Alisols)	45	24.06	Harmonized World Soil Database (2012)
			2-Soils conditioned by the parent material (Andosols, Arenosols, Vertisols)	13	6.95	
			3-Soils conditioned by the relief (Gleysols, Leptosols, Regosols)	31	16.58	
			4-Soils conditioned by limited leaching (Solonetz, Gypsisols, Calcisols)	15	8.02	
			5-Soils conditioned by a steppe environment (Chernozems, Kastanozems, Phaeozems)	7	3.74	
			6-Soils conditioned by pronounced movement of clay or ferric and hummus materials (Luvisols, Podzoluvisols, Podzols)	23	12.3	
			7-Soils conditioned by their limited age (Cambisols)	46	24.6	
			8-Sand dunes	7	3.74	
			Total	**187**	**100**	
Dominant Religion		Roman Catholic	Muslim	50	26.74	CIA (2012)
			Protestant	37	19.79	
			Roman Catholic	61	32.62	
			Indigenous	8	4.28	

			Orthodox	15	8.02	
			Buddhist	11	5.88	
			Hindu	4	2.14	
			Jewish	1	0.53	
			Total	**187**	**100**	
Forms of Government		Republic	Republic	80	42.78	CIA (2012)
			Parliament Democracy	37	19.79	
			Constitutional Monarchy	26	13.90	
			Communist	6	3.21	
			Parliament Republic	11	5.88	
			Federal Republic	13	6.95	
			Democratic Republic	5	2.67	
			Constitutional Democracy	4	2.14	
			Constitutional Republic	5	2.67	
			Total	**187**	**100**	

subgroup. Following that, the 187 countries equipped with a more complete range of data were persevered as the final sample size.

As the variables are completed, econometrics assessment began with the application of the open-source econometrics software of Gretl. The econometrics operation first analyzed the dependent variable of "Annual Rate of Forest Change in year 2005 to 2010" against all the independent variables. Adjacent to that, the standardized coefficient was calculated as:

$$\mathbf{B_n' = B_n * (SD_{Xn}/SD_Y)}$$

Where	$\mathbf{B_n'}$	= Standardized Coefficient of Independent Variable, X_n
(Wooldridge, 2008)	$\mathbf{B_n}$	= Slope Coefficient of Independent Variable, X_n
	$\mathbf{SD_{Xn}}$	= Standard Deviation of Independent Variable, X_n
	$\mathbf{SD_Y}$	= Standard Deviation of Dependent Variable, Y

With reference to the standardized coefficient that expressed the effect of a variable on another without the regard to how differently the variables are scaled, the model was condensed down to those significant variables.

Following the establishment of the core of model, these core variables underwent the next stage of comparative analysis with Chow Test against the null hypothesis of:

$$\mathbf{H_0 = B_1^A = B_1^B = B_1^C ... B_1^n;\ B_2^A = B_2^B = B_2^C ... B_2^n;\ ...;\ B_{10}^A = B_{10}^B = B_{10}^C ...\ B_{10}^n}$$

Where,	$\mathbf{B_{1\text{-}10}}$	= Standardized Coefficient of Ten Independent Variables
(Wooldridge, 2008)	**n**	= Number of Subgroups

across four specific criteria of continents, climate zones, level of income and country status as developing nation. Omitting Antarctica as continent and dividing Eurasia into each separated component, the analysis conducted test across six continents of Africa, Asia, Europe, North America, Oceania and South America. While for climate zones, the Köppen Climate

Classification was adopted and classified the 187 countries into the four climate zones of Tropical, Arid, Temperate and Cold. On the other hand, both the grouping for the country status as developing nation and the countries' level of income which comprised of Low-income, Lower-middle-income, Upper-middle-income and High-income were collected from the World Bank.

Next, the fitted values of the model are plotted against the actual annual rate of forest change and then examined the normality of residuals. The outliers are identified and further investigation on the possible justification was conducted.

Results and Discussion

The **Model 1** comprised of the ten variables that survived from the original independent variables and their subsequent dummy variables and **Table 3** indicated the standardized coefficient of the variables.

In the category of *Environmental Variation*, the *"Difference in Elevation"* exhibited a positive sign and that fulfilled the initial expectation of which forest at elevated region is subjected to less deforestation due to it lack of accessibility. On the other hand, the variable of Soil_3 and Soil_4 are respectively the *"Soil Conditioned by the Relief"* and *"Soil Conditioned by Limited Leaching"*. The World Soil Resources from FAO justified that the *"Soil Conditioned by the Relief"* are composed of the soil type of Gleysols, Leptosols and Regosols. The soil of Gleysols is often waterlogged at a shallow depth and that characteristic is particularly suitable for bunded rice growing. Hence, with appropriate drainage system, these lands can be transformed for arable cropping, dairy farming, horticulture and tree crops. On the other hand, the soils of Leptosols and Regosols dominate in regions with eroding landscapes. Leptosols that remained under natural vegetation can be converted into land for grazing and forestry. Whereas for Regosols in warmer and wetter climates can be used for dry farming but with the condition of regular supplementary irrigation. The *"Soil Conditioned by Limited Leaching"* is comprised of Solonetz, Gypsisols and Calcisols. Solonetz is soil which excess in sodium and formed at environment with a pronounced dry season, and Gypsisols is soil in arid region that formed through the dissolution from calcium sulphate and clustered together into gypsum crystals. These two types of soils are capable to be reclaimed with sufficient investment and make into good use to produce wheat. For Calcisols that accumulated calcium carbonate, this layer of soil is potentially fertile and rich in mineral for fodder crops, sunflower, cotton and grazing.

The *Socioeconomics Processes* segment of the condensed model is composed by four variables of "*Composition of Age Group Older than 65 years old*", "*Composition of Agriculture in GDP*", *"Countries with Zero Cereal Production"*, and *"Countries with Zero Share of GDP in Agriculture"*. The first variable indicated an intriguing result which justified the theory by Moran et al. (2004) of the implication of aging population on the change in land use pattern. Its standardized coefficient indicated that when the percentage of population increase by one standard deviation, the annual rate of forest change will increase by approximately 0.15 standard deviation, on average. Furthermore, the negative outcome for the effect of a nation's engagement in agriculture is correspondent to the intuition of country that more dependent on cultivation would demand more forest to be clear and that echoed the argument by DeFries et al. and Burgess. Whereas for the nations that do not produce cereal, the model demonstrated that their forest area experienced a 0.15 standard deviation increase annually. However, the dummy variable of *"Countries with Zero Share of GDP in Agriculture"* contradicted to the initial expectation that country that does not involved in agriculture would underwent positive growth in forest area. The negative coefficient of the variable demonstrated the existence of a negative coefficient between that independent variable to rate of deforestation. Hence, further extend of research was done to figure out the possible explanation for that contradiction. It is shown that all the countries that have zero agriculture are mostly limited in area of land mass such as the city-state of Singapore. Due to its limited land mass, Singapore only retained a lone fragment of 50-hectare rainforest and transformed the rest into more commercially efficient usage.

The section of *Pattern of Energy Consumption* is represented by the sole surviving variable of *"Volume of Energy Consumed"*. The result from the model exhibits a positive correlation between energy consumption and annual rate of forest change. Coherent to the hypothesis by Asafu-Adjaye (2000), countries that have a standard deviation more in the usage of a kilogram of oil equivalent per capita, on average the forest area would subsequently increase by standard deviation of 0.12.

Both the variables of *"Participation in International Conventions and Agreements"* and *"Countries with Federal Republic Form of Government"* in the *Governance* segment of the model illustrated negative effect on the annual rate of forest change. The result from countries' involvement in international treaties and convention proven the idea of "market leakage" that proposed by Santilli et al. (2005). On the other hand, countries with government form of federal republic has approximately 0.13 standard deviation higher rate of deforestation. An interesting point to be noted is that both Brazil and Indonesia which accounted for 51 percent of emissions from forest loss are actually function as a federal republic (The Global Intelligence, 2012). In a federal republic-form of government, power is divided between the federal and its subdivisions such as states. Hence, in the case of Indonesia, although national forest reserve management does exist to curb deforestation, it is the local authority that does not uphold the responsibility. In a report by Bisson et al. (2003) for the Office of Environmental Management, it is highlighted that weak governance is the root of deforestation in Southeast Asia (2003). That paper shed light on how the right of forest land is captured by state through corruption and various other illicit measures. Consequently, the forest area would be exploited in exchange for more economic profits.

Model 1: OLS, using observations 1-187

Dependent variable: Forest_Change

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	0.381015	0.48173	0.7909	0.43005	
Diff_in_Elevat	6.83409e-05	4.52445e-05	1.5105	0.13271	
Soil_3	-0.446995	0.226146	-1.9766	0.04965	**
Soil_4	-0.816477	0.313874	-2.6013	0.01008	**
Age_over_65	3.60389	1.877	1.9200	0.05647	*
Agri_GDP_Percen	-0.0190727	0.00762491	-2.5014	0.01328	**
Zero_Cereal	0.784805	0.431986	1.8167	0.07096	*
Zero_Agr_GDP	-1.36319	0.775559	-1.7577	0.08054	*
Energy_Consumpt	5.50614e-05	3.4776e-05	1.5833	0.11514	
Convent_Treaty	-0.0901808	0.0543221	-1.6601	0.09867	*
Fed_Republic	-0.638656	0.341718	-1.8690	0.06329	*

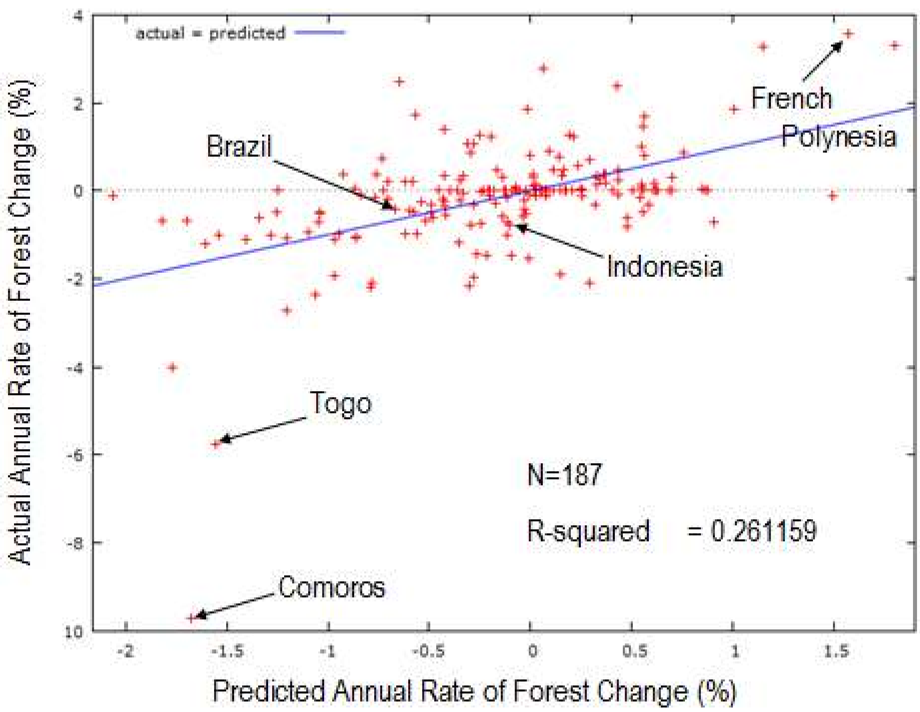
Mean dependent var	-0.151176	S.D. dependent var	1.281403
Sum squared resid	225.6499	S.E. of regression	1.132299
R-squared	0.261159	Adjusted R-squared	0.219180
F(10, 176)	6.221100	P-value(F)	4.01e-08
Log-likelihood	-282.9079	Akaike criterion	587.8158
Schwarz criterion	623.3580	Hannan-Quinn	602.2176

Table 3: Standardized Coefficient of Condensed Variables

Standardized Coefficient	
Environmental Variation	
Difference in Elevation	0.106314
Soils Conditioned by the Relief (Gleysols, Leptosols, Regosols)	-0.13007
Soils Conditioned by Limited Leaching (Solonetz, Gypsisols, Calcisols)	-0.17353
Socioeconomics Processes	
Composition of Population in Age Group Older than 65	0.149103
Composition of Agriculture of a Nation's GDP	-0.20914
Countries with Zero Cereal Production	0.150493
Countries with Zero Share of GDP in Agriculture	-0.13402
Energy Consumption	
Volume of Energy Consumed	0.120762
Governance	
Participation in International Convention and Agreements	-0.12938
Countries with Federal Republic Form of Government	-0.1271

After the construction of the final model, the fitted value that signifies the prediction by the model is plotted against the actual value of annual rate of forest change and it is shown in **Graph 1**. This scatter plot illustrates the projection of the model whereby dots that closer to the trend line satisfy the prediction of the model better. Indicated by the tight upward-sloping line, the actual and predicted rate of deforestation is positively correlated as majority of the nations follow tightly to the trend line. As the final model only manage to explain about 26% of variation in the rate of deforestation (R-squared = 0.26), it does not have a 45°upward slope. Both Brazil and Indonesia are situated near to the regression line and that demonstrated that the model did a fairly good job in explaining the actual value of deforestation.

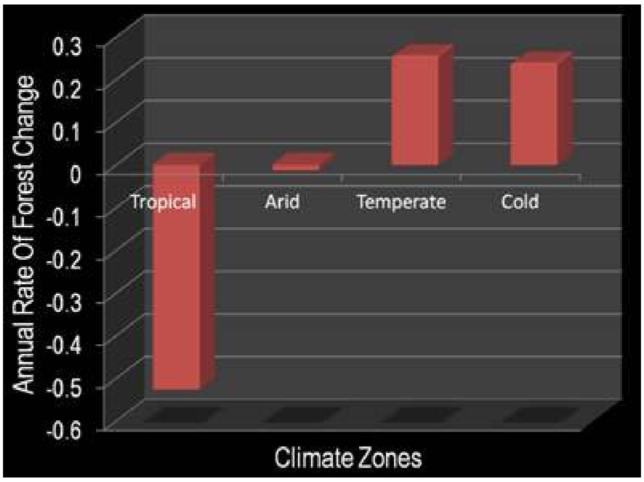
Graph 1: Actual vs. Predicted Annual Rate of Forest Change



Following the visualization of the model, the outliers were identified through analyzing the normality of residuals. Residuals are obtained by subtracting the actual rate of deforestation from the expected rate of deforestation forecast from the designed model. It reflects on whether does the model been designed appropriately and outliers which does not fit into the general trend indicated that there are elements of variation that unexplained by the fitted model. Illustrated in the graph are the two outliers of Togo and Comoros whose forest area decrease most rapidly. The economy of Comoros, which is described as one of the world's poorest nations, is heavily dependent on agriculture as the sector contributed 40% towards its GDP and made up a large sum of the nation's income from export. The three main cash crops exported by Comoros are vanilla, cloves and ylang-ylang whose falling international prices have impacted the cultivation of these intensive farming crops (ICTSD, 2008). On top of that, its poor management of land resource has give rise to the severe issue of soil degradation and erosion that bring forth by the practice of cultivating crop on slopes without proper terracing. Whereas for the case of Togo; its problem of deforestation is attributed to its swidden approach of cultivation and its strong dependence on woodfuel. Cotton accounts for 40% of the country's export earnings. Furthermore, being among the world's largest producer of phosphate, large area of forest is cleared for phosphate mining.

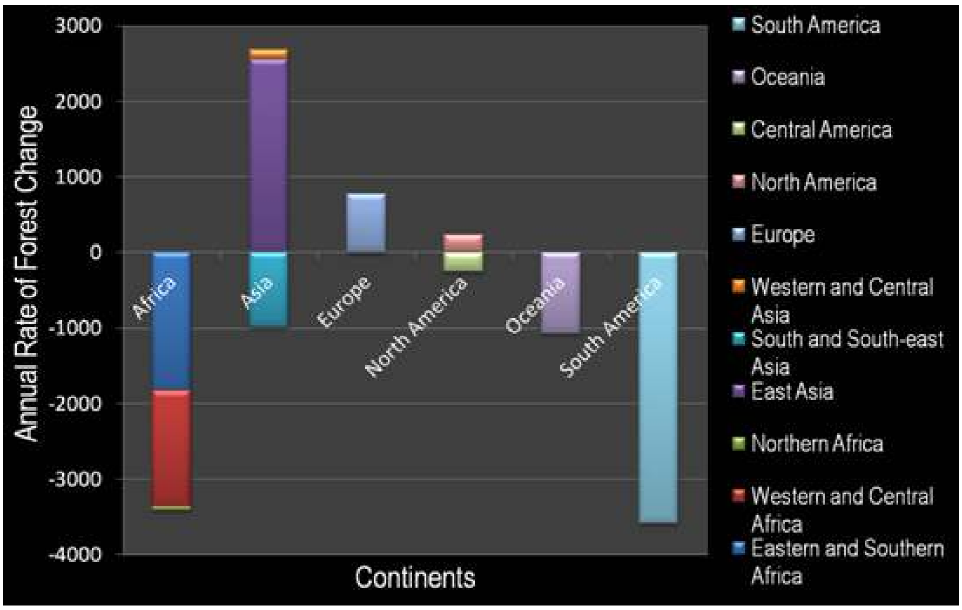
The next stage of interpretation involved comparative analysis through the application of Chow-test to test for disparity in pattern of deforestation across different subgroups. The trend of deforestation does differ among the climate zones of Arid, Tropical and Cold. In addition to that **Graph 2** illustrated the varying degree of deforestation in all four climate zones.

Graph 2: Global Annual Rate of Forest Change by Climate Zones in Year 2010

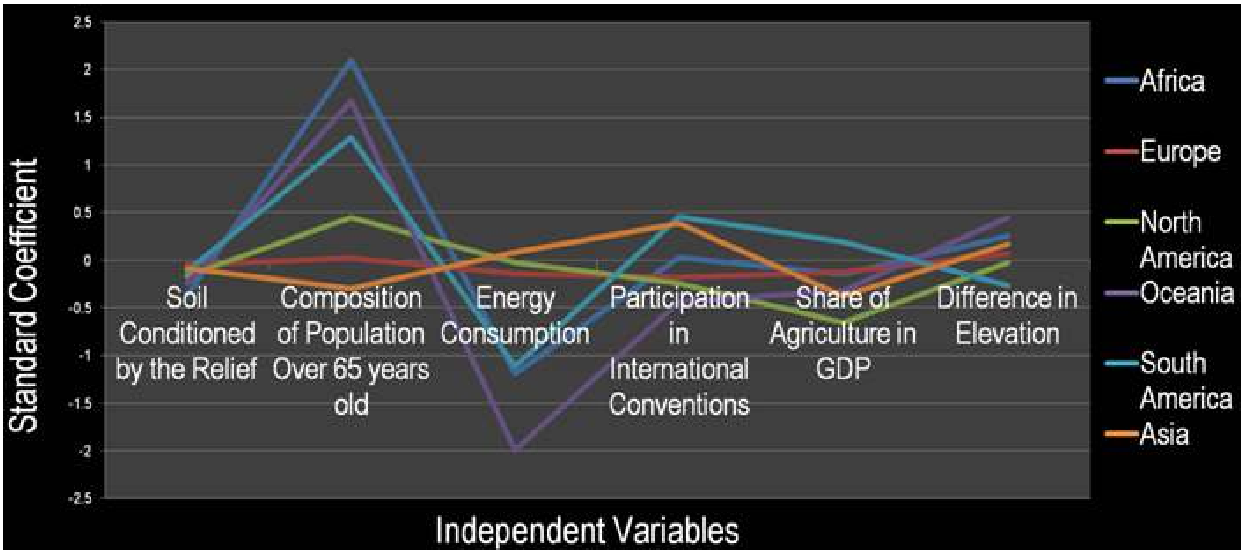


On the other hand, across the four continents of Africa, Asia, North America and South America, the marking of deforestation are distinct from one and another. **Graph 3** exemplifies the adverse rate of forest change within each continents and **Graph 4** compares the differing magnitude of the independent variables from the condensed model. The deforestation in Europe which pointed out to have high resemblance with the model has a considerably flat line in contrast to continent like Asia that often distinctly different the rest.

Graph 3: Global Annual Rate of Forest Change Across Continents in Year 2010

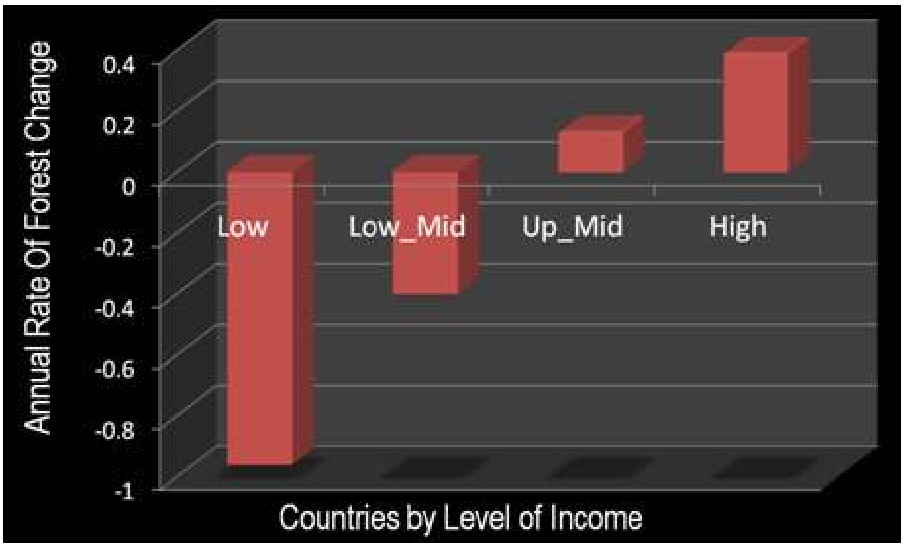


Graph 4: Comparison of Independent Variables Across Continents



Comparative analysis also takes in account the implications of disparity of economies. Hence, investigation was carried out on how deforestation changes accordingly to level of income. The outputs of Chow-test validate the asymmetries in deforestation and the visualization of **Graph 5** justified that. It is demonstrated that deforestation concentrated at low-income economies and as moving upward in the spectrum of level of income, the rate of deforestation decrease and these high-income economies experienced positive growth in forest area.

Graph 5: Comparison of Independent Variables Across Level of Income



However, in contrast to the initial expectation on that developing countries would have varying degree of deforestation; the model surprisingly refuted that suggestion. Perhaps that comes down to the fact that of the 187 countries that examined, the model is dominated by 136 developing countries. In short, these results suggest the asymmetries of deforestation as it spans across different geographical sites and disparity in economic wellbeing.

Conclusion

Although the condensed model does not fully explain the observed variation in deforestation, the four major categories of variables of *Environmental Variation, Socioeconomics Processes, Pattern of Energy Consumption* and *Governance* do exemplified the importance of expanding the scope in explaining deforestation. In spite of the fact that *Socioeconomic Processes* segment of the model demonstrated a substantial correlation to deforestation, it encompassed a wider spectrum of other variables than merely population pressure and economic development. Hence, researcher should not neglect the individual contexts but sensitive to the asymmetries of diverse spectrum of processes in driving deforestation.

However, there are still plenty of spaces for improvement for this research. Recommendations for future directions involve incorporating time series analysis in monitoring the trend of deforestation through time. Moreover, in order to improve the explanatory capacity of the model, variables that could act as possible proxy for unmeasurable variables such as the swidden method should be identified and included into the econometrics model. In addition to that, as indicated by the comparative analysis on the importance of localized analysis, the research can focus on a narrower scope such as a continent, a subcontinent, a country or even just a particular region. Other than that, a more rigorous econometrics analysis can be applied to investigate the lag of different variables' impact of deforestation and to present and analyze the model diversely. Backward analysis on the causation of deforestation will be another interesting question to be solved where rather than construct a model to predict the rate of deforestation and point out the possible causation, one can tracked back from the output of rate of forest clearing to its origin to detect not only the active agents but also the rest of variation which unexplained by the model.

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